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15.2 CURRENT ACTIVITIES AND CAPABILITIES OF THE TERRESTRIAL ENVIRONMENT GROUP  
AT NASA'S MARSHALL SPACE FLIGHT CENTER

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## 1. INTRODUCTION

The National Aeronautics and Space Administration (NASA) designated Marshall Space Flight Center (MSFC) the center of excellence for space transportation. The Aerospace Environments and Effects (AEE) team of the Electromagnetics and Aerospace Environments Branch (EL23) in the Systems Analysis and Integration Laboratory at MSFC, supports the center of excellence designation by providing near-Earth space, deep space, planetary, and terrestrial environments expertise to projects as required.

The Terrestrial Environment (TE) group within the AEE team maintains an extensive TE data base. Statistics and models derived from this data are applied to the design and development of new aerospace vehicles, as well as performance enhancement of operational vehicles such as the Space Shuttle. The TE is defined as the Earth's atmospheric environment extending from the surface to orbital insertion altitudes (~90 km).

## 2. DATA BASES

The AEE team develops and maintains a large and diverse TE data base obtained in real-time as well as in archived form (Table 1). Major emphasis is on data from NASA's Kennedy Space Center (KSC) and the Air Force Eastern Range (ER) because the Saturn/Apollo programs used the range in the past, and the Space Shuttle program launches from this range. However, because of the requirements for Transatlantic Abort Landing (TAL) and alternate end-of-mission sites, data bases were also developed for these sites. With the advent of new programs such as X-33, X-34, X-38, Bantam, and others, new launch/landing sites are being considered which necessitates development of additional data bases for the new sites.

These data are received in many forms via various media such as tapes, floppy disks, hard copy, and file transfer protocol (ftp) from sites around the world. In near real-time receipt is by the Meteorological Information Data Distribution System (MIDDS) which uses the Man-computer Interactive Data Analysis System (McIDAS).

Archival/retrieval of these TE data bases requires the use of several different computer systems at MSFC. Numerous programs ensure the quality and integrity of the data, and put the data into a format easily used by any computer system. These TE data bases provide analysis for solving engineering problems.

## 3. MODELS

The TE data bases are applied establish risk levels for various TE variables critical to aerospace vehicle design. Surface observations, including temperature, humidity, pressure, wind speed and direction, visibility, cloud cover, precipitation events, etc., are also applicable to vehicle design. Areas include the analysis of vehicle ground operations, vehicle on-pad exposure to the elements, on-pad fatigue loads due to winds, pad clearance during launch, and rocket exhaust diffusion. Profiles of wind and atmospheric thermodynamic variables, including temperature, humidity, pressure, and density from the surface to orbital insertion altitudes are also important in vehicle design. Examples of a profiles application include vehicle ascent and re-entry trajectory and loads analyses/simulations, energy requirements for vehicle control during ascent and re-entry, and aerodynamic heating.

Terrestrial environment design criteria are based on statistics and models that establish risk levels of atmospheric variables for aerospace vehicle design, mission planning, and operations trade studies. Several models developed by the AEE team at MSFC aid in the development of TE design criteria.

For flight vehicle mission planning and analysis, the Mission Analysis Program (MAP) was developed to establish risk relative to assigned atmospheric constraints of a flight vehicle. The MAP uses these vehicle flight constraints as inputs. Then, by examining a record of meteorological observations, MAP calculates the risk of a flight delay due to assigned constraints. These constraints may consist of either design values or specified flight rules such as no flight through thunderstorms, precipitation, or a cloud ceiling height  $\leq 3$  km (10,000 ft) (Johnson, et al., 1993). A typical application of this model is the determination of the risk of a No-Go condition. For example, if a launch constraint for each of several atmospheric variables exists, and a violation of any one of these constraints results in a No-Go condition, then probability that at least one of these constraints will occur is the probability of interest (Smith, et. al., 1992).

A wind profile model, the Vector Wind Profile Model (VWPM) was developed for the evaluation of launch

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vehicle control and trajectory variables. Vector wind profiles are derived from statistical models. A profile is built using the concept that for a given wind vector at one altitude, the conditional distribution of the wind components at any other altitude is bivariate normal. This process produces wind profiles that are a reasonable substitute for actual measured wind profiles. This model can be used to produce dispersions in aerodynamic load indicators for a launch vehicle at a selected altitude with only twelve model wind profiles, instead of using an extensive set of actual atmospheric wind profiles (Adelfang, et. al., 1994). An example of a set of twelve vector wind profiles for a reference altitude of 12 km is shown in Figure 1. Currently there are VWPM's for KSC and Edwards Air Force Base (AFB).

In order to address the needs for a design reference atmosphere that provides (1) complete global geographical variability, (2) seasonal and monthly variability of thermodynamic variables and wind components, and (3) altitude coverage from surface to orbital altitudes, the Global Reference Atmospheric Model (GRAM) was developed. A unique feature of GRAM is the ability to simulate spatial and temporal variations of atmospheric parameters such as fluctuations due to turbulence and other perturbation phenomena along a vehicle trajectory (Justus and Johnson, 1997). Figure 2 shows an example of perturbed density profiles produced using GRAM.

A detailed summary of the above mentioned models and a wide variety of TE statistics and risks that are provided by the AEE team at MSFC are found in the NASA Technical Memorandum *Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development, 1993 Revision* (Johnson, 1993). This document is an excellent TE reference, particularly for KSC/ER, for the aerospace vehicle design engineer.

#### 4. SPACE SHUTTLE DAY-OF-LAUNCH SUPPORT

MSFC/EL23 is responsible for Space Shuttle Day of Launch (DOL) upper winds analysis. Using the data bases discussed herein, MSFC developed the upper winds criteria for verification and certification of the Space Shuttle systems. On the DOL MSFC monitors the upper winds to ensure that the winds are within the verification/certification data base guidelines.

The DOL process actually starts at launch-minus-two (L-2) days by performing an end-to-end test of the wind measuring/processing/analyzing system. Three different wind measuring systems are used for DOL monitoring: (1) Jimsphere balloons tracked by FPS-16 radar from the surface to 17.0 km (56 000 ft) in 30.5 m (100 ft) altitude increments (this wind profile is used for vehicle wind loads calculations), (2) Rawinsonde balloons transmit a signal which is processed by the Meteorological Sounding System to yield wind, temperature, pressure, and dewpoint temperature from the surface to 30.5 km (100 000 ft) in 305 m (1 000 ft) increments, and (3) the 50 Mhz Doppler Radar Wind Profiler (DRWP) which measures the wind from 1.2 km (4 000 ft) to 18.0 km (60 000 ft) in 137 m (450 ft) increments. To insure data integrity, all three sources of data are used.

All data sources are processed and loaded into the MIDDS. This makes the data available to all users in near real-time for analysis for the various launch requirements. At L-8.5 hr a rawinsonde balloon is released and processed. This data is used to compare the L-6.25 hr jimsphere balloon profile and the DRWP profiles which are processed every five minutes. The L-6.25 hr jimsphere profile is analyzed to determine if any problems with the upper winds exist, and to check out the total system for problems. Another jimsphere balloon is released at L-4 hr to generate the DOL aerodynamic loads (l-load) file and to uplink it to the Space Shuttle. This profile becomes the basis for comparing all subsequent wind profiles. There are jimsphere releases at L-3 hr, L-2 hr, L-70 min, and at L+15 min. All profiles are analyzed and compared to the L-4 hr profile to ensure no change in the winds goes outside the certification/verification wind change envelopes (Figure 3). Also, wind shear analysis is performed on each profile to ensure no wind shear is outside the certification/verification data base. The 5-min DRWP profiles are continuously analyzed to insure that changes between the jimsphere balloon releases are within limits. Also, the DRWP profiles give the capability of monitoring the wind to 5 min prior to launch.

At L-30 min a rawinsonde balloon is released to provide temperature, dewpoint temperature, pressure, and winds between 17.0 km (56 000 ft) and 30.5 km (100 000 ft) for constructing the final meteorological flight profile. The rawinsonde profile along with the L+15 min jimsphere profile, the Range Reference profile, and the GRAM profile are used to construct the meteorological profile from the surface to 122.0 km (400 000 ft). This profile is used for all post flight performance analysis.

#### 5. SUMMARY

The MSFC AEE team is an integral part of MSFC's center of excellence, primary missions, and associated programmatic assignments. Much of this support includes providing statistics and models from the TE data base for developing TE criteria and requirements in the design of new and innovative propulsion systems, and improvement of current launch vehicle systems such as the Space Shuttle.

The AEE team also provides launch support to the Space Shuttle program by monitoring atmospheric winds to ensure they are within the vehicle's verification/certification data base for safety and reliability.

The Aerospace Environments and Effects team is committed to provide world class terrestrial environment support and to ensure optimized development of more dynamic and robust aerospace vehicles in the future.

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Table 1. A listing of the types of data archived at MSFC from various locations.

Upper Altitude Observations	Surface Observations	Range Reference Atmospheres
KSC/ER VAFB/West Range Edwards AFB White Sands Missile Range, CA Wallops Island, VA Great Falls, MT Kodiak, AK	KSC/ER VAFB Edwards AFB White Sands Missile Range, CA Wallops Island, VA McDill AFB, FL Orlando, FL Roberts Field, FL Palmdale, CA Agadir, Morocco * Casablanca, Morocco * Moron, Spain * Ben Guerir, Morocco * Banjul, Gambia * Zaragoza, Spain *	Ascension Island Barking Sands, HI Cape Canaveral, FL Dugway Proving Grounds, UT Edwards AFB Eglin AFB Fairbanks, AK Kwajalein Missile Range Nellis AFB, NV Point Mugu, CA Shemya Taquac Thule, Greenland Vandenberg AFB Wake Island Wallops Island, VA White Sands, NM

\* Space Shuttle TAL site

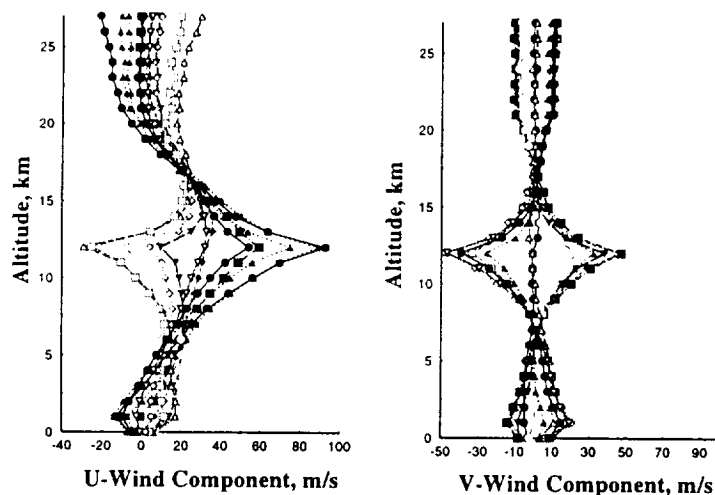


Figure 1. Example of Vector Wind Profile Model annual ( monthly enveloping ) profiles for Kennedy Space Center at a reference altitude of 12 km. The U component is E-W, and the V component is N-S.

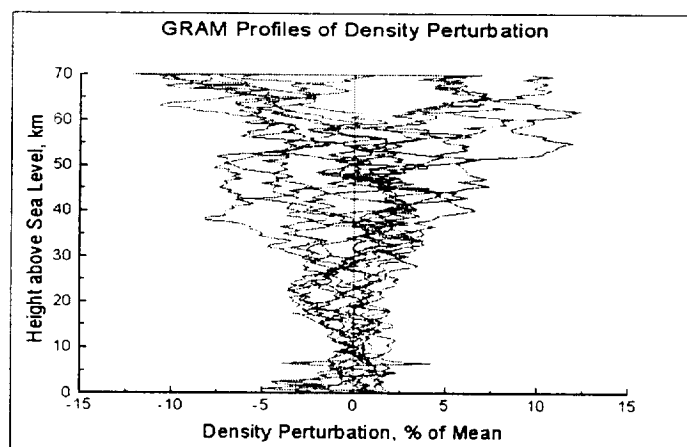


Figure 2. Example GRAM output showing perturbed atmospheric density profiles.

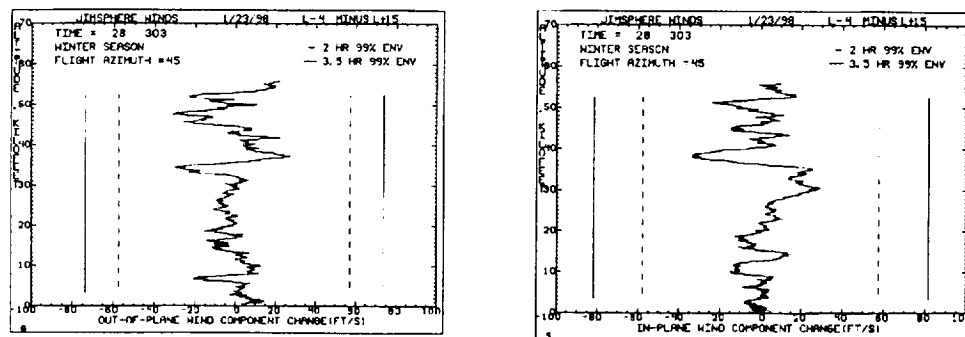


Figure 3. An example of 4 hr wind change plots Space Shuttle for post flight analysis. Vertical lines are limits of certification/verification change envelopes over 2 hr and 3.5 hr periods for the in-plane and out-of-plane ( U and V wind components relative to the Space Shuttle ). The profile in is the difference in the wind components from the L-4 hr and L+ 15 min (4 hr change).